Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development of Guidelines to Establish Effective and Efficient Timelines and Incentives for ABC		**5. Report Date** October 2018 6. **Performing Organization Code**
7. Author(s) Alice Alipour and Jennifer Shane		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Bridge Engineering Center Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.**
12. Sponsoring Organization Name and Address Accelerated Bridge Construction University Transportation Center Florida International University 10555 W. Flagler Street, EC 3680 Miami, FL 33174	U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology and Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590	**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**

15. Supplementary Notes

Visit www.intrans.iastate.edu for color pdfs of this and other research reports from the Bridge Engineering Center at Iowa State University.

16. Abstract

Accelerated bridge construction (ABC) techniques are rapidly gaining acceptance as an alternative to conventional construction to reduce construction duration and minimize the impact of closures at the network level. There are different types of ABC and each technique has its limitations and speed of completion. The choice of using ABC depends on a host of different factors including the availability of capital funds for its implementation, its impact on the traveling public, and the socio-economic aspects. While there are many states that have implemented a multitude of different ABC techniques, the decision making process to choose ABC over conventional construction cost, the type of ABC technique used, and the associated timelines and incentives for faster completion are not clear.

This report aims to address this aspect through a review of the available literature and interview with a few states that have implemented ABC at different levels. It appears that the major aspects impacting the timelines for ABC projects are the impacts the closures might have on the socio-economic aspects of the community. While most states acknowledge the importance of indirect costs, except for some, there is no mathematical formulation to account for hem in the final decision making. Most of decisions are made based on the qualitative input from districts and through public discussions with the public. For the establishment of incentives, similar procedure as those for the conventional construction and following the FHWA guidelines is suggested by most of the states.

17. Key Words		18. Distribution Statement	
accelerated bridge construction—timelines—incentives—contracting methods		No restrictions.	
19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified.	Unclassified.	21	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

DEVELOPMENT OF GUIDELINES TO ESTABLISH EFFECTIVE AND EFFICIENT TIMELINES AND INCENTIVES FOR ABC

Final Report
September 2018

Principal Investigator
Alice Alipour, Assistant Professor
Department of Civil, Construction and Environmental Engineering
Institute for Transportation, Iowa State University

Co-Principal Investigator
Jennifer Shane, Associate Professor
Department of Civil, Construction and Environmental Engineering
Institute for Transportation, Iowa State University

Authors
Alice Alipour, and Jennifer Shane

Sponsored by
Accelerated Bridge Construction University Transportation Center and
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

A report from
Bridge Engineering Center
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
www.intrans.iastate.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This project was supported by the Accelerated Bridge Construction University Transportation Center (ABC-UTC at https://abc-utc.fiu.edu/) at Florida International University (FIU), as the lead institution, with Iowa State University, the University of Nevada-Reno, the University of Oklahoma, and the University of Washington as partner institutions. The authors would like to acknowledge the ABC-UTC support.

The research team would like to extend special appreciation to the ABC-UTC and the U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology for funding this project.

EXECUTIVE SUMMARY

Accelerated bridge construction (ABC) techniques are rapidly gaining acceptance as an alternative to conventional construction to reduce construction duration and minimize the impact of closures at the network level. There are different types of ABC and each technique has its limitations and speed of completion. The choice of using ABC depends on a host of different factors including the availability of capital funds for its implementation, its impact on the traveling public, and the socio-economic aspects. While there are many states that have implemented a multitude of different ABC techniques, the decision making process to choose ABC over conventional construction cost, the type of ABC technique used, and the associated timelines and incentives for faster completion are not clear.

This report aims to address this aspect through a review of the available literature and interview with a few states that have implemented ABC at different levels. It appears that the major aspects impacting the timelines for ABC projects are the impacts the closures might have on the socio-economic aspects of the community. While most states acknowledge the importance of indirect costs, except for some, there is no mathematical formulation to account for hem in the final decision making. Most of decisions are made based on the qualitative input from districts and through public discussions with the public. For the establishment of incentives, similar procedure as those for the conventional construction and following the FHWA guidelines is suggested by most of the states.

INTRODUCTION

The aging infrastructure of the transportation system and the ever-increasing demand on the system has resulted in a large demand on the state departments of transportation to find approaches to rapidly replace and repair and build new highway infrastructure. Accelerated Bridge Construction (ABC) techniques are quickly receiving acceptance as an alternative to conventional construction for their capability in reducing construction duration, improving work zone safety, improving quality of construction, minimizing the traffic maintenance duration, minimizing the project costs, and the continuing advancements in industry that make the implementation of ABC methods feasible. Traffic disruption due to construction has been reduced to several hours with the development of state-of-the art construction technologies compared to conventional bridge construction techniques that required months of restricted traffic movements. The procedure has gained momentum for construction of bridges on routes with heavy traffic and also as a means of emergency bridge restoration.

When accounting for the costs associated with ABC construction two aspects needs to be accounted for: 1) the direct costs associated with the construction that is estimated in tax dollars and 2) the indirect costs associated with the disruption in normal flow of traffic which translates into socio-economic costs such as those stemming from drivers' delay, demand on detours, and opportunity losses. When deciding on whether a conventional vs. ABC technique one needs to account for the total cost stemming from both components of direct and indirect costs. Multiple research and implementation studies have discussed the different aspects with selection of ABC over construction cost in Utah [1], California [2], and Washington [3]. These projects have shown the feasibility of using different ABC techniques for removal and replacement of bridges in a short amount of time. Examples of smaller scale projects have also been shown by Iowa DOT [4] and Wisconsin DOT [5] that were able to use advantages of shorter closure times using pre-manufactured modular bridge components. The goal of this project is to develop a series of general guidelines that could be used as the basis for decision making on adoption of ABC techniques in novice states such that enough justification for investing higher direct costs could be made.

REVIEW OF ACCELERATED BRIDGE CONSTRUCTION TECHNIQUES

ABC techniques are the bridge construction techniques that innovative contracting, planning, design, environmental process, materials, and construction methods are used during projects [6]. Reduction of road closure times, traffic disruption, and user costs, in addition to improvements in construction quality utilizing prefabricated elements are attractive qualities of the implementation of ABC techniques. ABC techniques, initially reserved for routes with large average daily traffic (ADT) and critical thoroughfares, has significantly improved and increased in popularity. For example, the successful applications of ABC techniques helped nine transportation agencies to reduce bridge construction time and save over 30 million dollars [7]. Additionally, improvements of ABC techniques at different bridge elements and systems have enhanced the durability of bridge structures [8,9]. Due to the specific features pertaining to bridge site conditions, weather, and terrain at the bridge locations, not all ABC techniques can be implemented on a specific site. This is an important factor that needs to be accounted for in any DDS developed for this purpose. The following subsections provides the unique definitions, superiorities and inferiorities of each ABC technique and common contracting methods for the bridge replacement.

Prefabricated Bridge elements (PBES)

Prefabricated bridge elements are a commonly used ABC method and can be incorporated into most bridge projects as a form of accelerated construction. In this approach bridge elements are prefabricated, transported to the construction site, placed in the final location, and tied into the rest of the structure. The approach can be used to replace an entire bridge or just parts of it. The PBES can be used in combination with other ABC techniques as well. PBES allows for high-performance of the structure in the long term due to controlled conditions of fabrication and reduction of on-site construction time. They allow for production of multiple elements of the bridge at once and under similar construction conditions which could be used for bundled design and replacement of bridges.

Geosynthetic Reinforced Soil – Integrated Bridge Systems (GRS-IBS)

Geosynthetic Reinforced Soil-Integrated Bridge Systems (GRS-IBS) are composed of two main components: Geosynthetic Reinforced Soil (GRS) and Integrated Bridge Systems (IBS). GRS is an engineered fill of closely spaced alternating layers of compacted fill and geosynthetic reinforcement that eliminates the need for traditional concrete abutments. IBS is a quickly-built, potentially cost-effective method of bridge support that blends the roadway into the superstructure using GRS technology. This integration system creates a transition area that allows for uniform settlement between the bridge substructure and the roadway approach, alleviating the "bump at the bridge" problem caused from uneven settlement. The result of this system is a smoother bridge approach. The technology allows for simple construction, potentially lower initial cost, safer, more cost-effective, longer-lasting structure, faster construction time, less dependency on weather.

Slide-in Bridge Construction (SIBC)

This method requires that the new bridge to be built in parallel to the proposed finished location. The structure is normally built on a temporary support frame that is equipped with rails. The bridge can be moved transversely using cables or hydraulic systems. Several different methods have traditionally been used to slide a bridge into place such as pushing with hydraulic ram or winches to slide a bridge on a smoot surface or rails. Some modifications to the technique includes the longitudinal launch of the bridge. The method is one of the most expensive techniques within ABC and is shown to be beneficial on replacement of bridges on arterial roads. Major aspects limiting the use of the SIBC are limited right of way for staging, geometric constraints, lack of SIBC, profile changes in vicinity of the bridge, and impact on existing utilities.

Self-Propelled Modular Transporter (SPMT)

SPMT is a combination of multi-axle platforms operated through a state-of-the-art computer-controlled system that is capable of pivoting 360 degrees as needed to lift, carry, and set very large and heavy loads of many types. They are majorly used to move and place large bridge prefabricated elements. Thy result in drastically shortening the construction time and consequently significantly reduce traffic disruption and improve work zone safety and improve quality and constructability, enhance quality and lower life-cycle costs, reduce environmental impacts, and increase contractor and owner options. The major limitation to the technique are significantly higher construction cost, limitations imposed by the length and geometry of the travel path, availability of bridge staging area, and the supporting soil.

Incremental Launching Method (ILM)

Bridges are mostly of the box girder design and work with straight or constant curve shapes, with a constant radius. 15 to 30 meter box girder sections of the bridge deck are fabricated at one end of the bridge in factory conditions. Each section is manufactured in approximately one week. The technique results in minimal disturbance to surroundings including environmentally sensitive areas, smaller, but more concentrated area required for superstructure assembly.

Innovative Contracting Methods

The traditional approach in most states is the Design-Bid-Build (DBB) which involves the design and construction to be completed by two different entities. Project schedules using the DBB method are elongated because the design and construction cannot be completed concurrently. In addition to the technical methods leading to implementation of ABC as discussed in section 2, the everyday counts (EDC) initiative includes innovative contracting and project delivery methods that are used as a method to shorten the project duration or ensure the completion of project in the designated time.

Design-Build (DB)

This is an accelerated project delivery method in which the design and construction phases are combined into one contract thereby eliminating the separate bid phase in the traditional design-bid-build method which in turn allows certain aspects of design and construction to take place at the same time. The D/B process requires the designer-builder to assume responsibility for both the design and construction of the project. This method increases the risk for the design-builder, and reduces the risk for the owner. Project delivery time can be reduced, since the D/B process allows for the design and construction phases to overlap

Construction Manager/General Contractor

This is an accelerated project delivery method which occupies the middle ground between the traditional DBB and DB. In a typical CM/GC scenario, the owners of a project hire either a general contractor or design firm to serve as the construction manager, placing responsibility for design review, design modifications, system integration, and construction with that single contractor. CMGC allows the DOT to remain active in the design process while assigning risks to the parties most able to mitigate them. As with the design–build approach, there are potential time savings because of the ability to undertake a number of activities concurrently. It should be noted that the state legislation should allow for the CM/GC structure to be implemented in state DOT contractors.

A+B Bidding

This is a Cost-Plus-Time bidding procedure. The low bidder is selected based on a combination of the contract bid items (A) and the time bid for construction times the daily road user cost (B). The days bid become the contract time. The low bidder is selected based on a combination of the traditional contract unit price items based bid (A) and the time component proposed by the bidder to complete the project or a critical portion of the project (B). The time to complete the project (B) is assigned a monetary value and combined with the contract items based bid (A) to select the contractor. The bidder with the lowest overall combined bid (A+B) is awarded the contract. Under the A+B method of contracting, the DOT contractually recognizes that there is a monetary value for each working day that can be eliminated from the contract. Further, a contractor who can work faster, at a higher cost, may provide the best value to the public.

Incentives/Disincentives

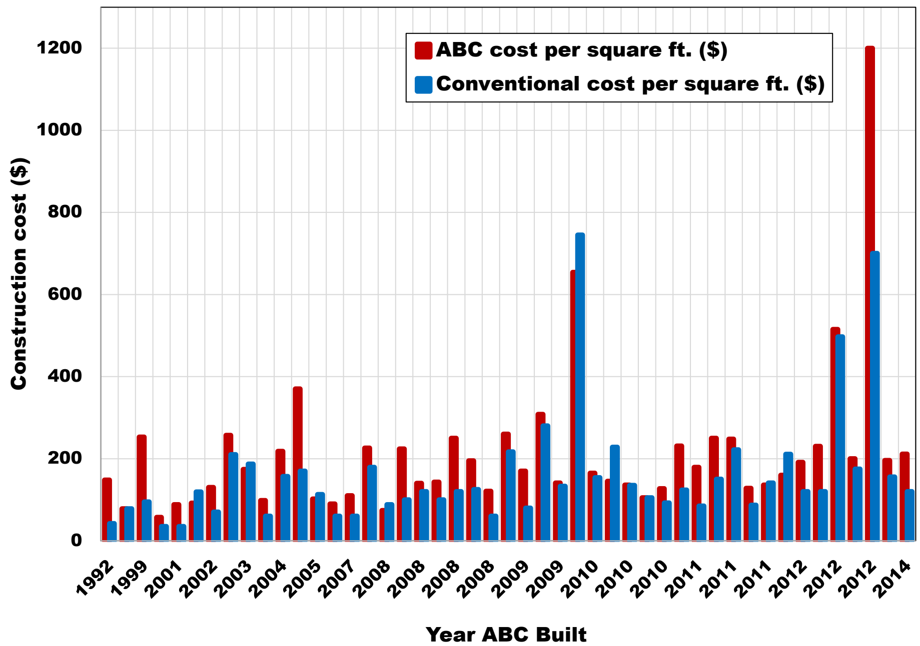
This is a contract provision which compensates the contractor a set amount of money for each day that the identified critical work is completed ahead of time and assesses a deduction for each day the contractor overruns the time. I/D provisions are primarily intended for those critical projects where traffic inconvenience and delays are to be held to a minimum. FHWA Technical Advisory defines liquidated damages (LDs) as follows: the daily amount set forth in the contract to be deducted from the contract price to cover additional costs incurred by a state highway agency because of the contractor's failure to complete all the contract work within the number of calendar days or workdays specified or by the completion date specified. The determination of an appropriate I/D dollar amount is critical for maximizing the potential for project acceleration. FHWA suggests that I/D amounts should be based on SHA overhead, traffic control and detour costs along with RUCs on a project-by-project basis. The I/D amount must provide a favorable cost/benefit ratio while covering the contractor's acceleration costs (based on extended shifts with extra workers for seven days a week).

The ABC techniques and innovative contracting methods can significantly reduce the project duration and provide a better construction environment for workers while resulting in more durable structures. One of the most extensive databases for the completed ABC projects was reviewed to collect information on the construction costs of ABC projects [10]. Figure 1 shows the results where 83% ABC projects have higher costs compared to equivalent convention construction costs (Figure 1, left). The average additional construction cost of all projects on ABC techniques compared to the conventional reaches up to 48.9% (Figure 1, right) which agrees with the general consensus on ABC techniques being more costly. Consequently, there is a necessary to integrate the project-level and network-level studies to find the suitable ABC technique for every bridge and use their saving effects on bridge closure time and the transportation system to offset their high construction costs.

AVAILABLE DECISION MAKING TOOLS

Accelerated bridge construction (ABC) has received significant recognition and popularity as a method to construct and rehabilitate bridges in recent years [17]. ABC uses both new technology and innovative project management techniques to mitigate the effects of bridge construction on the public, reduce construction costs, promote traffic and worker safety, and improve the bridge durability due to standardized and controlled construction conditions [18]. The perceived higher initial costs associated with ABC is often times cited as a reason for less inclination towards its adaptation for repair and replacement projects [19]. Another major factor contributing to this hesitancy is the unavailability of decision support systems (DSS) that would help with selection of appropriate techniques. Multiple research in the field of infrastructure management have addressed DDS for bridges. These research have been majorly focused on either detailed assessment of the total life cycle analysis of the bridges under deterioration mechanisms and selection of maintenance actions for individual bridge. As for the availability of DDS there are three tools that are available. The first one developed by FHWA is based on a framework for prefabricated bridge elements and systems decision making, where a flowchart and matrix incorporating a set of decision criteria are used to help decision makers choose between conventional and accelerated bridge construction alternatives [20,21]. The second approach is a method to evaluate the construction plans based on factors such as safety, accessibility, schedule performance, and budget performance where a scoring system based on experts opinion is used to prioritize the construction plans [22]. The third method is based on analytic hierarchy processes (AHP) [23,24] that uses pairwise comparisons to evaluate the importance of defined factors relative to other factors using either a numerical or verbal scale [25]. The analytic hierarchy process consists of three components: the overall goal of the decision, a hierarchy of criteria by which the alternatives will be evaluated, and the available alternatives [26].

While many states have developed ABC Design and Decision making guidelines (e.g., [2–4,27–29]), the decision making process developed by Utah DOT seems to be the most holistic one [1]. The Utah DOT ABC decision making process consists of two steps: completing the ABC rating procedure and then using the rating in the ABC decision flowchart to determine if an ABC approach is required.



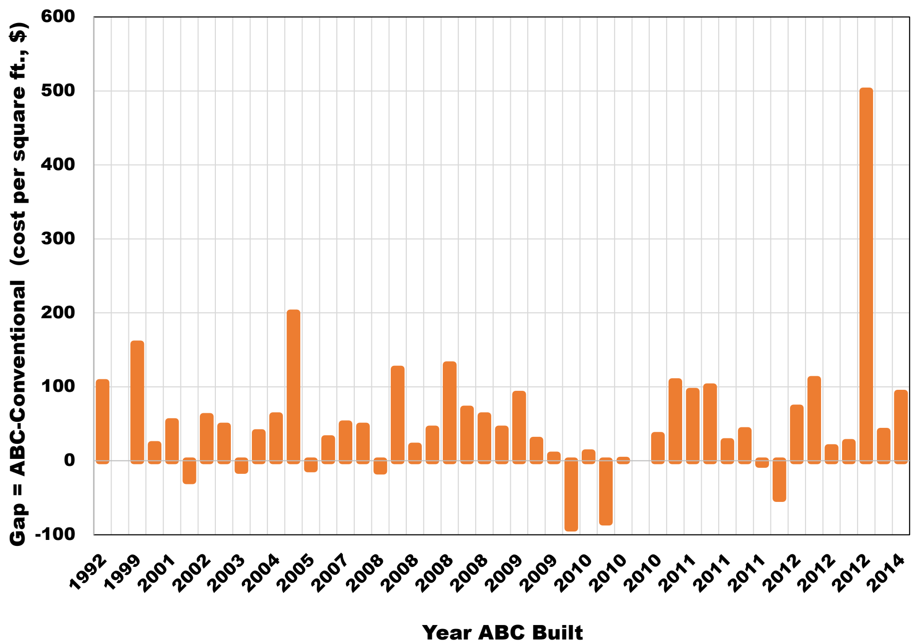


Figure 1. The comparison of ABC vs. the conventional construction cost estimates (Top) Comparison of construction cost of conventional and ABC bridges, (Bottom) The difference between ABC and conventional construction cost

ACCELERATED BRIDGE CONSTRUCTION RATING PROCESS

A set of measures are defined as follows and a rating scheme is assigned to assess the applicability of the ABC to the bridge project. This will allow for the preliminary design team to justify the need for use of ABC at a specific site. Most of the available decision making guideline use a scoring system which then is integrated with some modified version of the AHP tool. This stage is for the concept team to initially assess the applicability of ABC to bridge construction process. The score technically acts as a filter by ranking the suitability of bridge replacement candidates for ABC based on a set of measures. Table 1 provides a list of the available measures and a list of the states that use them as a means to score the ABC technique in comparison with conventional construction. Aside from the ABC measures that are used for scoring purposes to decide whether an ABC technique is a suitable choice for bridge construction in a specific construction, there are no specific guidelines on the how the decisions are made on assignment of duration to projects and use of user cost contracting methods such as Incentive/disincentive. This projects goal is to provide guidelines for estimation of direct and indirect costs associated with the project duration and how it could impact decisions on whether ABC techniques should be used instead of conventional construction techniques.

Table 1. ABC technique measures by states (synthesized from: [add references])

	CA	IA	MN	OR	UT	WA	WI
Average daily traffic (ADT)	×	×	×		×	×	
Out of distance travel/detour length		×	×	×			×
Delay/detour time	×			×	×	×	
Bridge classification					×		
User costs	×	×	×		×	×	×
Economy of scale	×	×		×	×	×	×
Use of typical details					×		
Safety				×	×		
Railroad impacts	×				×	×	×
Accessibility of navigation channels							×
Weather-related impacts	×					×	×
Environmental impacts	×			×		×	×
Preference of the districts	×					×	
Traffic and maintenance	×			×		×	
Utility impacts	×					×	
Historical impact				×			
Traffic density			×				
Construction cost		×		×			×
Right of way				×			
Toll revenue				×			
Revenue loss				×			
Construction personnel safety				×			×
Physical constraints				×			
Emergency replacement							×
Impact to economy						×	×

DETERMINATION OF APPROPRIATE ABC TECHNIQUE

FHWA manual on ABC techniques lists six major techniques and combinations thereof that could be used. Determination of each technique is dependent on a host of different factors that could also be related to the ABC measures earlier. Additionally, aspects such as the requirements of the site, site geometrics, and project funding play an important role on selecting the type of ABC technique used. In general ABC techniques could be categorized as: offsite and onsite construction projects. Offsite construction techniques build the bridge outside of the final location using normal construction and/or prefabricated elements. Once construction is complete, the bridge is moved into place. These include the Self-propelled modular transporter (SPMT) moves, lateral slides, longitudinal launches and crane based ones. It should be noted that in general SPMT systems due to the need for special equipment turn out to be more expensive than a lateral slide for a single move. The higher costs could be alleviated if multiple bridges at the site use this technique. Lateral slides seem to be the most cost effective among the offsite techniques. Longitudinal slides and crane-based techniques cost somewhere between SPMT and Lateral slides, while the longitudinal slides require more design effort.

As part of this project the data base of ABC projects collected at the FIU ABC-UTC website was reviewed. From the 111 projects reported in the database, only 47 have the detailed project schedule included. The schedule of the 47 projects was reviewed and the closure duration (impact on traffic in days) was extracted from the schedule. Figure 2 shows the traffic impact rating (Tier 1 to 6) based on the reporting from the state and the estimated closure duration (for the projects with the reported schedule).

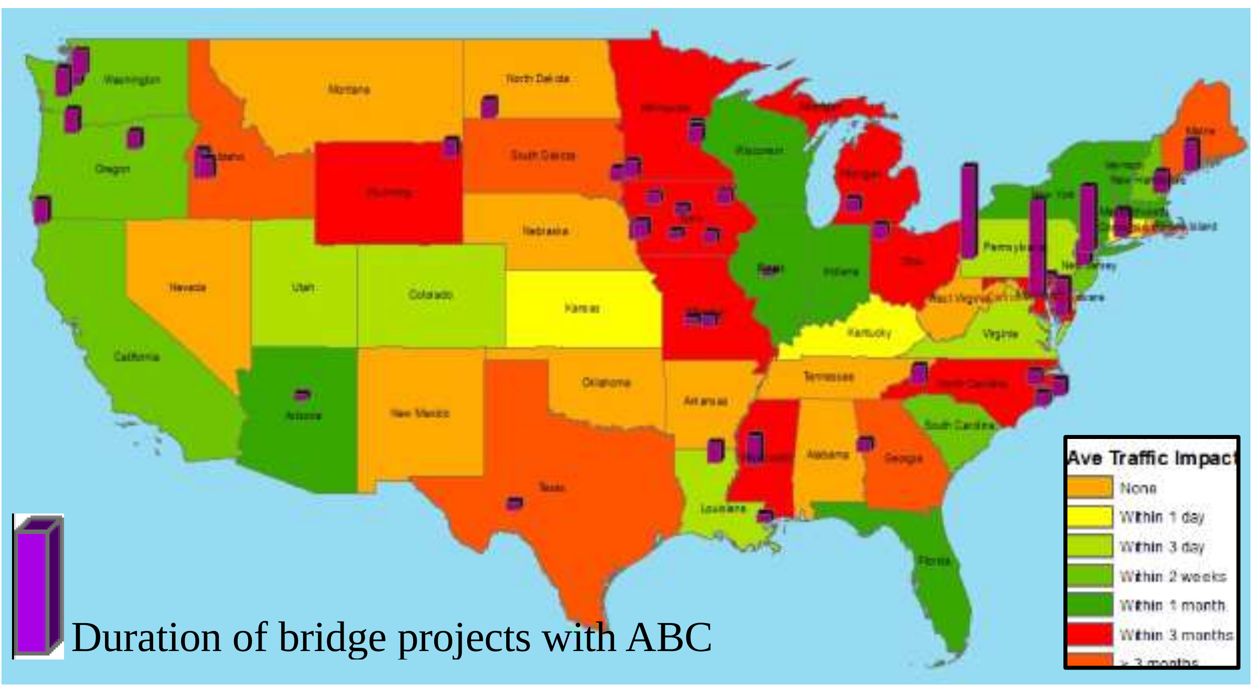


Figure 2. Tiers reported by state and closure duration on a project basis

For all the bridge projects in the data base, Figure 3 lists the relation between the bridge recorded ADT value and the duration of the project assigned. As it is observed, for the two main projects with the highest ADT of 298,000 and 248,000 had closure durations of 187 and 199 days and the project with the highest duration (745 days) had an ADT of 155,000. The average ADT considered is 34,915 and the average closure duration is 158 days. The minimum ADT on a bridge was 10 and the time to complete was 60 days. While there is general trend for the lower ADT projects to have a relatively higher durations (still not as much as those with higher

ADT), it is hard to establish a trend between the ADT and the duration of the project. One major factor contributing to this factor is that most likely bridges with higher ADT tend to be larger in terms of square footage requiring more closure time for replacement (even with the highest of the speed).

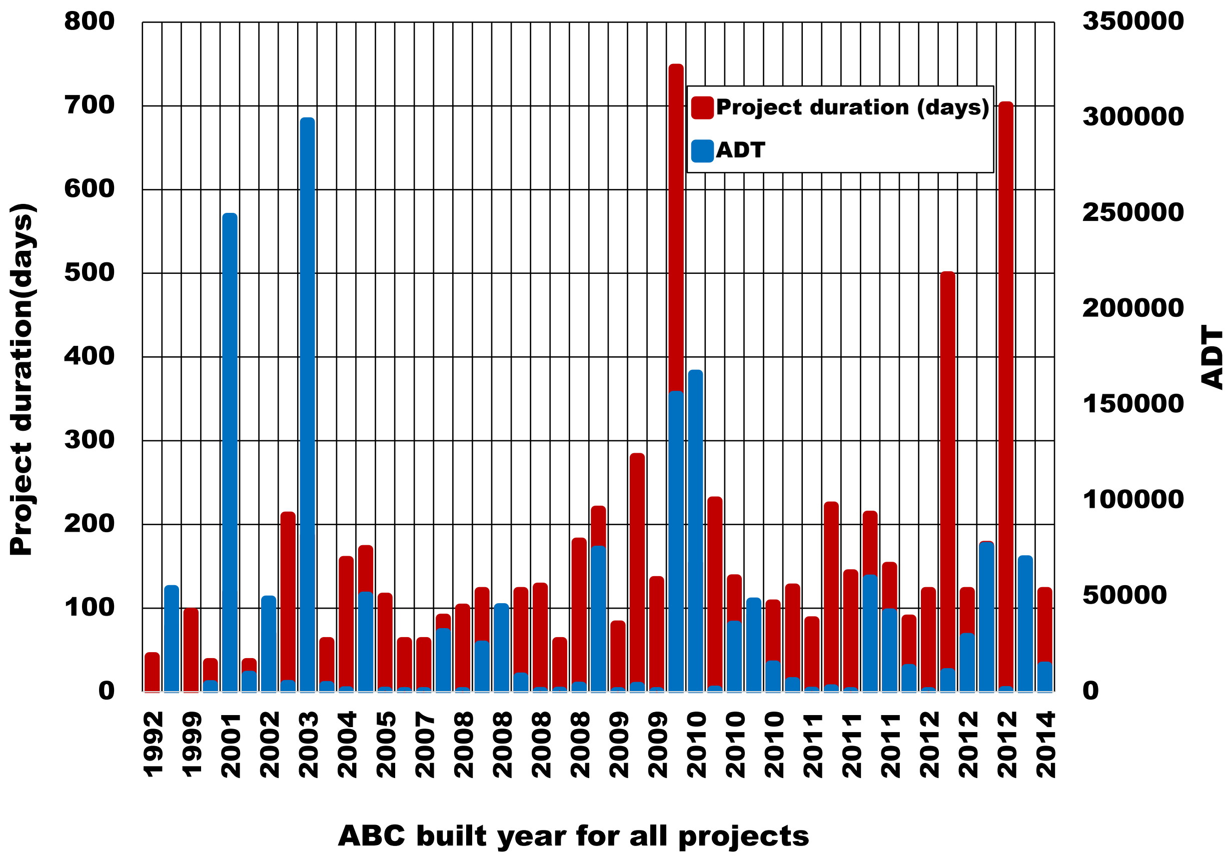


Figure 3. Comparison of the ADT and the project duration for the projects

USER COSTS

User cost is defined as the additional costs borne by motorists and the community at large as a result of construction activities [30]. The users cost can include components such as the user delay cost, vehicle operating cost, crash costs, and emission costs that are generally easier to estimate. There are other components such as noise, business, local, and community impacts that are often times harder to estimate.

The process of selecting infrastructure improvement projects, be it new roads, maintaining bridges, etc., is becoming increasing difficult with the rising need to be absolutely diligent with spending while keeping the growing number of drivers safe and satisfied with road conditions.

Each improvement option must be weighed out and its overall benefit to the community affected may become the deciding factor of the timing of its implementation or its existence as a whole. The benefit is determined through calculating user costs incurred during the construction process and comparing that to the user cost after the proposed improvement strategy. Transportation planners rely on analytic tools to evaluate the relative merits of each candidate project and ultimately provide a means for allocating resources to that set of projects that will maximize the total benefits. (Officials, 2003).

The road user costs (RUC) directly affects those traveling through project sites, and indirectly affect the surrounding areas such as the environment or local economics and urban growth. Just as the bulk of the literature reviewed for this discussion, the focus will be on these direct costs, as they are more easily quantifiable for a project. The overall benefit of a project or the particular sequencing for that project is determined by a multitude of travel costs. The AASHTO User Benefit Analysis for Highways manual, breaks the costs into three distinct categories: travel time costs, operating costs, and accident costs. Taken together, the total of these costs is essentially the price that travelers must invest on to travel (Officials, 2003). Review of some of the most prominent documents in RUC estimation shows that most transportation agencies use some type of combination of these when developing methodology for determining road user costs.

This manual focuses on the user benefits, which are determined by the user costs of a project. From this excerpt, one can understand the basic relationship between the two: when a comparison is made between the costs of traveling and the number of trips taken at each price level, a relationship is determined between the cost of travel and the demand for trips. When all users are aggregated together, the difference between the travel "price" that travelers are required to pay and what they would have been willing to pay is the user benefit affiliated with the trip. Any reduction in travel costs (i.e., trip price), then, will result in a benefit to the traveler. For example, with a cost reduction, users who were already making the trip receive the benefit of making the same trip at a lower cost (Officials, 2003). Therefore we can see that the main priority is to justify a project by its RUC, as it allows for a clear analysis of its benefits as well as a method for the direct comparison of different improvement projects.

The concept of totaling the user costs is simple and affordable. Most data is available, so long as proper sourcing and updating is completed. Total user cost is equal to the sum of the vehicle running costs (VOC), the value of travel time (VOT), and the accident costs (AC). After reviewing relevant literature, it could be concluded that most DOT’s RUC methodology consist of a combination of these three, with only a few exceptions. Some literature references outside or ‘off-site’ impacts in addition to the monetized impacts that can be quantified, but as seen by a recent survey when asked to rank order of importance of the user cost components, vehicle emissions were deem practically insignificant (Qin & Cutler, 2013). Figure 4 summarizes the RUC (Department of Transportation Federal Highway Administration (FHWA))

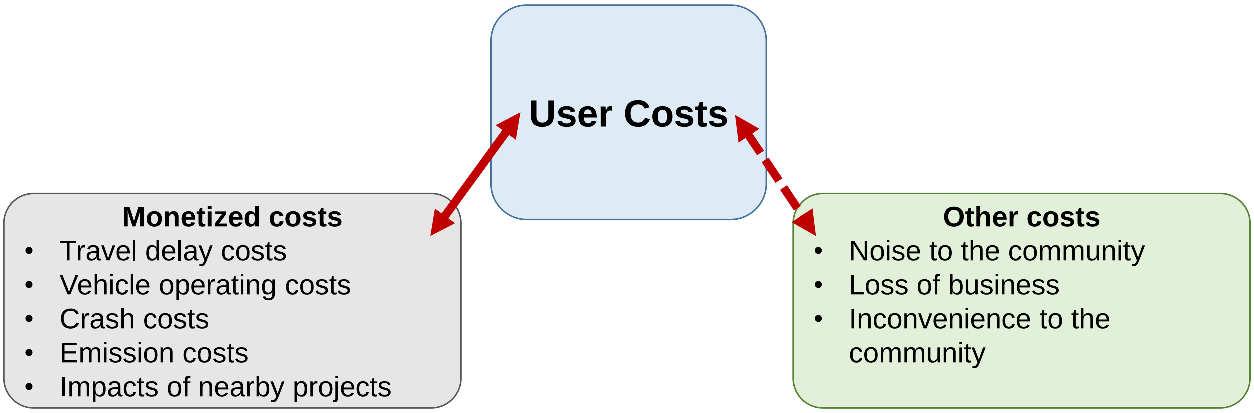


Figure 4. Breakdown of the user cost estimation (Adopted from Mallela & Sadasivam, 2011)

INCENTIVES/DISINCENTIVES

Incentives have been used for years on construction projects. These incentives have different means of motivation, including economic means, business relations, the legal system, and psychological stimulus. Incentives and disincentives in construction contracts has become commonplace among transportation agencies using all of these motivational tactics. The method and reasons for incentives vary greatly, and may include specifications and bonuses for increased workmanship on pavement, bonuses for early project completion or meeting milestones, liquidated damages for missed milestones, and procurement "points" for reduced disruptions to the traveling public.

Hughes et al. [31] note that incentives have been used in construction for many years. They cite work from 1953 regarding labor expenditures for companies using incentives and those not. The authors further cite work form 1967 discussing productivity in the home building industry that included modifications to contracts to "encourage more efficient working methods." The discussion continues to demonstrate that there are different ways to motivate contractors. These may be through economic means, business relations, the legal system, and psychological motivation.

Use of economic motivation is likely one of the most prominent, however, should not be the only means, especially when looking at different types of roadways and locations. A study of Missouri incentives and disincentives related to road user costs found that there was a greater effectiveness of road user costs for urban projects, full-closure projects, and emergency projects. Projects that were rural, non-emergency projects saw a savings of road user costs, but the incentives/disincentives were not on the same level as the other types of projects. (Sun et al. 2012)

Potential costs associated with increased delays and safety risks of drivers in work zones are utilized to determine road user costs. Higher road user costs for a work zone may trigger the use of incentives or disincentives. A study of Missouri incentive/disincentive projects from 2008-2001 found that for every dollar in paid incentives, there was approximately $5.30 of road user costs saved. The data also showed that incentives/disincentives on projects reduced both mobility and safety road user costs [32]. Ofili [33] reports that Utah experiences a 5:1-6:1 ratio of user costs saved to construction costs incurred on ABC projects. It is noted that these ratios may not have been experienced on the early ABC projects, but, “with repetition, costs have decreased.”

In a recently completed synthesis on practices for establishing contract completion dates for highway projects, Taylor et al. [34] report of 23 responding states, 17 believe that the use of incentives and disincentives influenced the on-time completion of contracts. The remaining five were unsure if there was an influence. A study from Michigan agreed with this finding, indicating that incentive clauses accelerated project schedules [35].

Fick et al. [36] interviewed 32 states and reported a perceived increase in cost of 10% or less for projects with incentives/disincentives associated with project schedule. They further report that, “on average, interviewees felt that the impact of [incentive/disincentive] provisions on costs was neutral.” Further research revealed that, “a competitive market environment is especially important for the effective use of [incentive/disincentive] provisions.” El-Fafy and Abdelhamid [35] found that yes, incentive clauses do increase project costs, but the additional costs are less than the avoided user delay. Smith [37] found that when incentives are included in contracts, the contractor often received the maximum allowable amount, ranging from $2,500-$10,000 per day. Taylor et al. [34] also found that incentives are more often paid than disincentives are collected.

Determining an appropriate incentive for early completion or disincentive for late completion can be problematic. In 2000, The Texas Transportation Institute and Texas DOT developed a set of tables to support development of road user costs. The tables simplify the process and make it easier for smaller districts to make informed choices [38]. Ibrahim and Orabi [39] propose a model to “quantify the impact of different levels of [incentive/disincentive] values on the trade-off between time and cost of pavement rehabilitation projects" and determine the costs of these projects. The authors propose that there is a normal point where construction costs are at a minimum and an increase or decrease in the project's duration will increase the project costs. Further, the authors propose that there may be multiple levels of incentives/disincentives based on the decrease in the project's duration. Finally, they claim the model is capable of determining how likely it is that each level of duration reduction is achieved. Other researchers have proposed other methods for determining incentives/disincentives. Researchers from Texas A&M propose a seven stage framework to support this decision [40].

Incentives/disincentives may be used on ABC projects to encourage shorter closure times. These may also be suggestive of closure timing. Reasons for closure timing may be to account for traffic patterns. An example of this may be seen from the Indiana DOT [41]. In this contract, liquidated damages were assigned for work completed after a specific date. Liquidated damages were also assigned for work before a specified start date or if work was started after a specific date, Table 1. Additionally, there are different rates, or disincentives, for lane closure on specific days of work. On this project, lane closures on Fridays cost more than lane closures on other days of the week. This project was awarded through an A+B model. The contractors were allowed to propose the number of days the roadway would be closed for bridge installation. To encourage the least disruption to the traveling public, Fridays (which were the highest traffic count days) were at a different rate than other days of the week. Proposers for the project proposed 13 closure days, starting on Saturday morning and opening up 13 days later (on a Thursday) so that there was only one Friday where the roadway was closed, thus minimizing the penalties, which in turn minimize the traffic disruption.

Table 2. ABC Liquidated Damages Rates (Indiana DOT 2017)

Description	**Liquidated Damages ($)**	**Rate**
Completion date	2,500	Per day
Earliest date to begin work	2,500	Per day
Latest date to begin work	2,500	Per day
Road closure	2,500	Per day
Interstate lane closure Saturday-Thursday	2,000	Per hour
Interstate lane closure Friday	2,500	Per hour
State road closure	4,000	Per day

INTERVIEW RESULTS

Caltrans has started the process of putting together a series of guidelines for decision making on selection projects for ABC techniques. From the engineering perspective, this DOT is working to establish a focused engineering group that exclusively deals with the design and contracting of the ABC projects. On each potential project, the districts communicate their intentions for the project such as the duration of closure, the timeline of the project to take place with the main design office and they are provided with the options for construction and contracting. It appears that at the current stage the final decision on whether the ABC is selected for a specific project relies heavily on the district. The factors going into this decision are those such as available funds, the impact of construction-related closure on the users' costs and opportunity losses, and seasonal considerations. To ensure that the contractors are aware of the special circumstances associated with the ABC projects such as the possible special equipment and the faster pace of the project, Caltrans holds informational sessions with the contractors before any bidding takes place— sometimes even having that as a requirement to be able to submit a bid.

Discussions with a private firm involved in design and delivery of the ABC projects highlighted the positive aspects of the construction manager/general contractor (CMGC) in the states that are allowed. This is a method that allows for the contractor to have their input in early stages of ABC projects which in the long run results in more cost-effective, long-lasting bridges with early completions.

The Minnesota DOT has used ABC on a number of projects using a number of different delivery methods and technologies. The Minnesota DOT has a defined process for selecting and implementing ABC. This is a three stage process. The first stage is to be completed during the scoping phase of the project. This stage is an initial screening and includes user costs, average daily traffic, detour length, amount of commercial traffic, and the traffic density. This evaluation is completed on all bridges and included in the MnDOT Project Scoping Worksheets. The rating during this stage can indicate that ABC maybe appropriate and should still be considered. Even if the first stage does not indicate a "Yes" rating, ABC may still be considered and a second stage evaluation may be completed if the use of ABC mitigates a critical issue identified during the scoping process. The second stage is to be completed prior to the project entering the State Transportation Investment Plan (STIP). If at the end of the second stage ABC is still a consideration, the third stage includes a discussion about project specific details, consideration of alternative delivery and contracting, and identifying the final construction method and contract administration. These stages are all completed engaging a committee or multiple parties to provide a variety of perspectives including the central office and the district office from the bridge engineers, traffic engineer, estimators, and construction engineer from different phases. (http://www.dot.state.mn.us/bridge/pdf/abc/memo.pdf).

The decision to use ABC techniques is based on the process described. Reasons for using ABC may include a short construction time, which may force ABC, a limited season, or high volumes. While these may be dictated by the DOT, a contractor may also decide to use ABC. In at least one instance the contractor proposing on a best value project using alternative delivery decided to propose use of ABC as a way to score additional points in the best value selection process.

Which ABC technology to use include trying different technologies, project specific characteristics, or environmental reasons.

If the closure or construction duration is determined by the DOT the DOT personnel will look at what has been seen on other projects, both ABC and conventional construction, looking at what other states have experienced, and judgement. This is a group discussion and the DOT feels that if an inappropriately short duration is mandated the contractors may comment during the bidding period. On one best value project, the contractor selected the duration. This was based on their experience. In this case the proposed duration by the contractor was not exceeded by approximately 10 days. The actual duration was approximately only 60% of what was expected using conventional construction.

Incentives are used on some projects, including ABC projects. The incentive is typically associated with the portion of work that is considered important by the DOT. Disincentives are also used. On at least one project the disincentive was approximately $10,000 per day for failure to complete the project on time.

There is not a one to one ratio between the incentive/disincentive and user costs. To determine user costs, an economic analysis is completed on each project. This includes delays, detour length, and traffic volume. The user costs are usually developed as a range. The Indiana DOT has completed two ABC projects. There is no formal process for selecting a project for ABC. ABC was selected for the second project based on the characteristics of the project site. This was determined during a site visit by the DOT and the design consultant. Plans were developed for two different ABC technologies. The project was let with both plan sets and the DOT left it to the contractor to see which design the contractors would select which plan set they would choose.

The duration was developed through talking with the construction engineers about the conventional portions of work with the addition of a discussion of the critical path of the ABC portions of the project. It was determined by the design consultant that nine days was the least feasible but limited the closure to 13 days to allow for differences. The closure was completed in nine days. The slide in of the bridge, when considering the entire project, is not through to be a significant issue in the critical path as long as it is done. The slide-in portion of the project is observed to generally take less than 12 hours. While the bridge is on the critical path, it does not dictate the entire closure duration as long as tasks are completed as scheduled, the approach work is what takes longer.

Incentives/disincentives were used on the second project based on the number of closure days that the contractors proposed. User costs were developed by the design consultant including user costs, detour costs, and delay durations. This resulted in a large value that was scaled back to what the DOT felt comfortable with to be incentives/disincentives. These incentives/disincentives were different for the various directions of the roadway and for different days of the week.

CONCLUSIONS

The purpose of this report is to collect information and provide guidelines as to how ABC project timelines and incentives are established. Discussions with multiple stated DOT representatives, review of existing literature, and detailed review of the ABC projects database showed the following results:

- In terms of decision making tools states with experience of implementing ABC could be categorized into three major categories: i) those that had adopted the AHP tool (such as Utah DOT and Iowa DOT) and followed a similar scoring scheme to make a decision on using ABC, ii) those that had adopted either a scoring system that was rather qualitative (such as Wisconsin DOT and Caltrans), and iii) those that used the help of a scoping group familiar with the time-cost requirements of ABC to make a decision.

- Understanding the importance of ABC, few states have adopted to create focus groups or central engineering offices dedicated to ABC. These groups normally acted as a consulting office to districts and other branches of the State DOTs to make decisions on establishing the timelines and costs associated with ABC.

- Incentives/disincentives have been part of the construction project contracting methods for a long time. The feedback seems to be a mixed one on the feasibility of I/D for ABC projects. This is mostly attributed to the previous experiences that states have had with establishing I/D for the conventional construction projects.

- It appears that other innovative contracting methods such as CM/GC are gaining momentum within the states. Most states and consultants involved with this type of contracting believed that the involvement of the owner, designer, and contractor form the beginning of the project allows for development of more effective construction solutions.

REFERENCES

[1] UDOT. UDOT Structures Design and Detailing Manual. 2017. doi:10.15713/ins.mmj.3.

[2] Caltrans. Guidelines for Preparation of Advance Planning Study Appendix A ABC Decision Making Guidance. 2015.

[3] DOT WS. Chapter 14 Construction Accelerated and Innovative Bridge Chapter 14 Construction Accelerated and Innovative Bridge. 2015.

[4] Abc I. TABLE OF CONTENTS ~ ACCELERATED BRIDGE CONSTRUCTION Accelerated Bridge Construction General Policy overview Design information 2018:1–20.

[5] Initiative WABC, Overview ABC. Chapter 7 – Accelerated Bridge Construction Table of Contents WisDOT Bridge Manual Chapter 7 – Accelerated Bridge Construction 2015:1–40.

[6] Michael P. Culmo PE. Accelerated Bridge Construction - Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems (No. FHWA-HIF-12-013). 2011.

[7] Prefabricated Bridge Elements and Systems. PBES Cost Study : Accelerated Bridge Construction Success Stories. 2006.

[8] Engineering B, State I. Synthesis on the Use of Accelerated Bridge Construction Approaches for Bridge Rehabilitation. 2015.

[9] Accelerated Bridge Construction University Transportation Center （ABC-UTC）. Strength, Durability, and Application of Grouted Couplers for Integral Abutments in Accelerated Bridge Construction. 2016.

[10] Accelerated bridge construction university transportation center n.d.

[11] Stark TD, Arellano D, Horvath JS, Leschinsky D. Guideline and Recommended Standard for Geofoam Applications in Highway Embankments(NCHRP Report 529). Nchrp Rep 529 2004:71. doi:10.17226/13759.

[12] Committee JA, Mujumdar V, Austin R, Guthrie JT, Hawkins NM, Johal LSP. Emulating Cast-in- Place Detailing in Precast Concrete Structures 2001:1–16.

[13] P. Culmo M. Connection Details for Prefabricated Bridge Elements and Systems 2009:568.

[14] Federal Highway Administration, American Association of State Highway and Transportation Officials, National Cooperative Highway Research Program, Florida Department of Transportation. Manual on Use of Self-Propelled Modular Transporters to Move Bridges. 2007.

[15] Engineering HB, Engineers H, Ralph L, Clyde WW, Cupples T. Slide-In Bridge Construction Implementation Guide 2013.

[16] Laviolette M, Wipf T, Lee Y, Phares B. BRIDGE CONSTRUCTION PRACTICES USING Incremental Launching 2007.

[17] Ralls ML. Accelerated Bridge Construction. Aspire 2007:16–20.

[18] Saeedi A, Emami S, Doolen TL, Tang B. A decision tool for accelerated bridge construction. PCI J 2013;58:48–63. doi:10.15554/pcij.03012013.48.63.

[19] Barutha P, Zhang N, Alipour A, Miller C, Gransberg D. Social Return on Investment As a Metric To Prioritize Use of. Transp Res Board, 96th Annu Meet 2017:1–14.

[20] Tang B. Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making. Proc. Second US-Taiwan Bridg. Eng. Work. San Mateo CA, 2006.

[21] Salem, S. and RM. Accelerated Construction Decision Making Process for Bridges. 2006.

[22] El-Diraby TE, O'Connor JT. Model for Evaluating Bridge Construction Plans. J Constr Eng Manag 2001;127:399–405. doi:10.1061/(ASCE)0733 9364(2001)127:5(399)#sthash.xqzGbyDJ.dpuf.

[23] Escobar MT, Moreno-Jiménez JM. A linkage between the analytic hierarchy process and the compromise programming models. Omega 2002;30:359–65. doi:10.1016/S0305-0483(02)00053- 1.

[24] Saaty T. The analytic hierarchy process: planning. 1980.

[25] Doolen DT, Saeedi A, Emami S. Accelerated Bridge Construction (Abc) Decision Making and Economic Modeling Tool. 2011. doi:TPF-5(221).

[26] Office of Bridges and Structures ID. Bridge Design Draft Manual. 2017. [27] DOT T. Accelerated Construction Guidelines 2018.

[28] DOT A. Rí o C [ac a o. n.d.

[29] DOT M. Benefit and cost analysis. n.d.

[30] Lee JH (Jay), McCullouch B. Review Construction Techniques for Accelerated Construction and Cost Implications-FHWA/IN/JTRP-2009/6 Final. JTRP Tech Reports 2009:1–102. doi:10.5703/1288284314299.

[31] Hughes, W., I. Yohannes, and J.B. Hillig. 2007. Incentives in Construction Contracts: Should we pay for Performance?. CIB World Building Congress.

[32] Sun, C., P. Edara, and A. Mackley. 2012. Use of Incentive/Disincentive Contracting to Mitigate Work Zone Traffic Impacts. Midwest Smart Work Zone Deployment Initiative, Iowa Department of Transportation, and Federal Highway Administration.

[33] Ofili, M. 2015. State of Accelerated Bridge Construction (ABC) in the United States. University Honors Program, Georgia Southern University.

[34] Taylor, T.R.B., R.E. Surgill, Jr., and Y. Li. 2017. Practices for Establishing Contract Completion Dates for Highway Projects. National Cooperative Highway Research Program. Transportation Research Board, Washington, D.C. Synthesis 502.

[35] El-Gafy, M. and T. Abdelhamid. 2015. Impact of I/D Contracts Used for Expediting Michigan's Road Construction. ASCE Journal of Construction Engineering and Management. Vol. 141, No. 7.

[36] Fick, G., E.T. Cackler, S. Trost, and L. Vanzler. 2010. Time-Related Incentive and Disincentive Provisions in Highway Construction Contracts. National Cooperative Highway Research Program. Transportation Research Board, Washington, D.C. Report 652.

[37] Smith, M.J. 1987. Incentives/Disincentives: Final Report. New Jersey Department of Transportation and U.S. Department of Transportation.

[38] Daniels, G. 2000. Adding up motorists costs: Simple look-up tables will help reduce construction delays. Texas Transportation Researcher. Texas Transportation Institute. Vol. 36. No. 2.

[39] Ibrahim, M. and W. Orabi. 2016. Quantifying the Impact of I/D Contracting on the Time/Cost Trade-Off for Pavement Rehabilitation Projects. ASCE Construction Research Congress.

[40] Choi, K., E.S. Park, and J. Bae. 2013. Decision-Support Framework for Quantifying the Most Economical Incentive/Disincentive Dollar Amounts for Critical Highway Pavement Rehabilitation Projects. Southwest Region University Transportation Center and Texas A&M.